Feasibility of Mechanical Properties of Lamina Hybrid Composite Ramie Fiber-Coconut Fiber-Fiberglass as an Alternative Hull Substitution of Material Structure Under 25M-V Type

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Abstract. The use of metals in ship components is increasingly reduced, this is because the metal has a heavy weight, a difficult manufacturing process, and easy to corrode. The ship components began to use non-metallic materials, such as composites. Composites commonly used in ship hull construction are fiberglass composites, this material is chosen because this material has strong, lightweight, rustproof and easy manufacturing processes. Fiberglass is a non-renewable material, so development needs to be done, one of them by utilizing natural fibers. The selected natural fibers are ramie fiber and coconut fiber, the choice of this material is based on the availability of abundant material and good mechanical properties. Then the specimen was made using a hand lay-up manufacturing method with a composition of the G-SSK-SR 90° and G 90° layer with BTQN 157 printed polyester, which was then subjected to tensile testing. From the test results it is known that the maximum tensile strength of the G 90° composite is more optimal than the G-SSK-SR 90° layer composite. Then the results of static simulation based on engineering thickness with the manufacturing method of these two composite variations can be declared feasible based on BKI mechanical standards and safety factor values.

Keywords: Mechanical Properties, Lamina Hybrid Composite, Material Structure

1 Introduction

The use of composites at this time is widely applied to marine ship construction structures, especially in the hull part of the ship because the use of composite materials can make optimal weight efficiency, but has high strength and stiffness. Composite material that is commonly used in marine boat hulls is fiberglass, fiberglass is widely used for ship hull construction because of its strong, lightweight, tough, rust-resistant, relatively economical, and easy manufacturing process, but fiberglass is a non-renewable material. difficult to decompose when it is not suitable for use, and the production still depends on exports.

There is a need for sustainable development of raw materials for composite reinforcing fillers that are environmentally friendly and renewable, such as natural fibers whose utilization has not been maximized and has not been intensified massively in Indonesia. This alternative material has several advantages, namely easy to obtain, low economic value, environmentally friendly and renewable. In this study, the alternative materials used were hemp fiber and coconut fiber as composite reinforcing fillers with a manufacturing process using

the hand lay up method for the manufacture of ship hulls. Utilization of hemp and coconut fibers is expected to reduce production costs for ship hull construction and increase natural resources, especially natural fiber, which is one of the alternative materials that can support fiberglass fillers for composite strength. The purpose of this study focuses on the types of variations. the most optimal sample based on the average tensile test results to determine the thickness according to BKI mechanical standards, material safety factor values, and manufacturing methods that match the criteria. Based on the results of this study, it is expected to be a breakthrough in terms of innovative material technology developments, especially in the maritime industry.

2 Materials and Methods

2.1 Design of Test Specimens

In accordance with the rules used by BKI 2015, the test specimens follow ISO 527 - 4. Dimensional planning of tensile test specimens according to the drawing.

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Fig.1. ISO 527-4 Specimen Design

2.2 Composite Composition

The composition for the lamination process refers to the standards of the Indonesian Classification Bureau, in

Table 1. Comparison of composite compositions

Type of Laminate	Material	Comparison of Resin/(Kg)
Fiber Lamination	-Katalis	(1 s/d 1,5)%, certain condition 2%
	-CSM300	(0,9 – 1,0) kg/m ²
	-CSM450	(1,1 – 1,2) kg/m ²
	-WR600	(1,5 – 1,6) kg/m ²
	-SSK	(0,9 – 1,0) kg/m ²
	-SR	(0,9 – 1,0) kg/m ²
Gelcoat	-Pigmen	(8 – 10) %
	-Aerosil	(0,6 – 1,0) %
	-Kobalt	(1,0 – 1,5) %

Table 2. Planning layer data

Item	Natural Fiber	Synthetic Fiber
Layer Composition	(G + CSM ₃₀₀ + CSM ₄₅₀ + SR + SSK + SR + CSM ₄₅₀ + CSM ₃₀₀)	(G + CSM ₃₀₀ + CSM ₄₅₀ + WR ₆₀₀ + CSM ₄₅₀ + WR ₆₀₀ + CSM ₄₅₀ + CSM ₃₀₀)
Thickness (mm)	7	7

2.4 Design of Test Specimens Static Stress Analysis Simulation Stages

In this study, a static stress simulation was carried out on the hull design, this was done to determine the critical point and maximum stress on the hull, where the maximum stress results would be compared with the maximum tensile stress of the test results. Later the results of this simulation are used as a reference for determining safe limits apart from BKI mechanical standards. For the Static Stress simulation using Solidwork 2018 software.

3 Result and Discussion

3.1 Design Mechanical Testing Result Data

Following are the results of the tensile test as shown in the graph and visual of the fracture of the specimen according to the pictures and drawings

this study for the composition of the composition ratio of natural fiber alloys following the mass / m² that is closest to the standard composition for synthetic fibers.[9]

2.3 Planning Layer

Table 2, shown a planning layer data, composition and thickness of natural fiber and synthetic fiber. The description of material as follow : G = Gelcoat, CSM 300 = Chopped Strand Matting 300c, CSM 450 = Chopped Strand Matting 450, WR600 = Woven Roving 600, SSK = Coconut Coir Fiber and SR = Hemp Fiber

a. Composite Tensile Testing Results Data G-SSK-SR 90°

Fig.2. Visual Fracture Results of G-SSK-SR 90° Composite Spesimens

Fig 3. Stress and Strain Graph of G-SSK-SR 90° Composites

Based on the graph of the test results of 10 samples of composite specimen G-SSK-SR 90°, it is known that the maximum average stress is 28.95 ± 1.55104982 MPa with an average modulus of elasticity of 767.4973489 MPa

b. G 90° Composite Tensile Testing Results Data

Fig.4. Visual Fracture Results of G 90° Composite Specimens

Fig.5. Stress and Strain Graph of G 90° Composites

Based on the graph of the test results of 10 samples of composite specimen G 90°, it is known that the maximum average stress is 86.93 ± 8.27799788 MPa with an average modulus of elasticity of 767.4973489 Mpa.

3.2 Design Planning for Optimization of Tensile Strength Based on Composite Thickness

Based on the results of the tensile test, it is known that the test results do not meet the mechanical standards set. So to get the optimal tensile strength and elastic modulus, one way that can be done is to engineer the thickness of the composite, the thickness of the composite is planned to achieve the mechanical standards set by the Indonesian Classification Bureau, where the thickness engineering is calculated based on the primary data from the tensile test results.

Table 3. Thickness Manipulation Data

Material Name	Thickness manipulation	Ultimate Tensile Strength (MPa)	Elastic Modulus (MPa)
Composite G-SSK-SR 90°	54,747	228,705	6063,229056
Composite G 90°	26,733	349,47468	6012,984859

3.3 Internal and External Factors in Static Hull Simulation

In the simulation process, the internal factors are obtained from the ship's cargo and the installation installed on the casco body, where it is known that the load obtained is 3671 N for 0% DWT load, 10022.95 N for 50% DWT load, and 15493.8 N for 100% DWT load. For the external factors obtained from the design pressure calculation at the hull bottom are known to be the bottom impact pressure 0.01034588378 MPa for 0% DWT load, 0.01067147991 MPa for 50% DWT load, and 0.01059947323 MPa for 50% DWT load.

3.4 Design Static Analysis of Hull with Variation of Load

This analysis is tested based on the primary data from the test results that have been processed by the author so that the data is the parameter in carrying out a static simulation on Solidwork 2018 software, then this data is then inputted into the simulation software, using Static Simulation.

In this static simulation, it only refers to the engineering thickness of each variation, the load load and the bottom impact pressure. The simulation results are stress, strain at each loading variation.

Composite analysis of G-SSK-SR 90 variation on Hull with Variation of Load

3.4.1 Static analysis at 0% DWT loading

Fig.6. Visual stress result for the G-SSK-SR 90° composite on a static simulation of 100% DWT loading

The simulation results under 0% DWT loading conditions at a water-laden height of 0.29 m and a hull thickness of 55 mm obtained a maximum stress of 8,641 MPa that occurs in the keel section, then the minimum stress occurs on the side hull section of 0.0122 MPa.

Fig.7. Visual strain result for the G-SSK-SR 90° composite on a static simulation of 0% DWT loading

The simulation results at 0% DWT loading conditions at a water-laden height of 0.29 m and a hull thickness of 55 mm obtained a maximum strain of 0.005982 that occurs in the keel section, then the minimum strain occurs in the side hull section of 0.00002303.2) Static analysis at 50% DWT loading

Fig.8. Visual stress result for the G-SSK-SR 90° composite on a static simulation of 50% DWT loading

The simulation results under 50% DWT loading conditions at a water-laden height of 0.35 m and a hull thickness of 55 mm, the maximum stress is 11.63 MPa which occurs in the keel section, then the minimum stress occurs on the side hull section of 0.02228 MPa.

Fig.9. Visual strain result for the G-SSK-SR 90° composite on a static simulation of 50% DWT loading

The simulation results under 50% DWT loading conditions at a water-laden height of 0.35 m and a hull thickness of 55 mm obtained a maximum strain of 0.007579 that occurs in the keel section, then the minimum strain occurs on the side hull section of 0.00001985

3.4.2 Static analysis at 100% DWT loading

Fig.10. Visual stress result for the G-SSK-SR 90° composite on a static simulation of 100% DWT loading

The simulation results under 100% DWT loading conditions at a water-laden height of 0.4 m and a hull thickness of 55 mm, the maximum stress is 13.77 MPa which occurs in the keel section, then the minimum stress occurs on the side hull section of 0.02900 MPa.

Fig.11. Visual strain result for the G-SSK-SR 90° composite on a static simulation of 100% DWT loading

The simulation results under 100% DWT loading conditions at a water-laden height of 0.4 m and a hull thickness of 55 mm obtained a maximum strain of 0.0103 that occurs in the keel section, then the minimum strain occurs in the side hull section of 0.00001807.

Composite analysis of variation G 90° on Hull with Variation of Load

1) Static analysis at 0% DWT loading

Fig. 12. Visual stress result for the G 90° composite on a static simulation of 100% DWT loading

The simulation results at 0% DWT loading conditions at a water-laden height of 0.29 m and a hull thickness of 27 mm obtained a maximum stress of 24.16 MPa that occurs in the keel section, then the minimum stress occurs on the side hull section of 0.09941 MPa.

Fig.13. Visual strain result for the G 90° composite on a static simulation of 0% DWT loading

The simulation results at 0% DWT loading conditions at a water-laden height of 0.29 m and a hull thickness of 27 mm obtained a maximum strain of 0.007669 that occurs in the keel section, then the minimum strain occurs in the side hull section of 0.00004771.

3.4.3 Static analysis at 50% DWT loading

Fig.14. Visual stress result for the G 90° composite on a static simulation of 50% DWT loading

The simulation results under 50% DWT loading conditions at a water-laden height of 0.35 m and a hull thickness of 27 mm, the maximum stress is 27.99 MPa that occurs in the keel section, then the minimum stress occurs on the side hull section of 0.1549 MPa .

Fig.15. Visual strain result for the G 90° composite on a static simulation of 50% DWT loading

The simulation results under 50% DWT loading conditions at a water-laden height of 0.35 m and a hull thickness of 27 mm obtained a maximum strain of 0.00913 that occurs in the keel section, then the minimum strain occurs in the side hull section of 0.00004213.

3.5 Design Safety Factor Analysis on each Load Variation

The safety factor is calculated based on the maximum tensile strength of the test results divided by the working stress based on the simulation :

Table 4. Table of composite safety factor for variation of G-SSK-SR 90°

Load Condition	Max Stress (MPa)	Yield Stress (MPa)	Safety Factor	Where
0% DWT Loading	8,64	28,95	3,35	Allowed
50% DWT Loading	11,63	28,95	2,50	Allowed
100% DWT Loading	13,77	28,95	2,1	Allowed
Average	11,35	28,95	2,65	Allowed

Of the three loading factors that refer to the hull simulation results using the G-SSK-SR 90° material, it meets the safety limit criteria.

Table 5. Table of composite safety factor variation G 90°

Load Condition	Max Stress (MPa)	Yield Stress (MPa)	Safety Factor	Where
0% DWT Loading	24,16	86,93	3,60	Allowed
50% DWT Loading	27,99	86,93	3,10	Allowed
100% DWT Loading	29,42	86,93	2,95	Allowed
Average	31.3653	86,93	3,22	Allowed

Of the three loading factors that refer to the hull simulation results using G 90° material, it has met the safety limit criteria.

4 Conclusion

Through the use of spatial analysis such as topographic operations, proximity calculation, buffer construction, raster reclassification, and intersection operations, GIS-based studies may be beneficial in a broad variety of disaster assessment applications including Tsunami vulnerability. The susceptibility to tsunamis varied according to slope, elevation, land use, distance from the shore, and distance from the river in the studied regions. The area designated as very vulnerable covered 157,10 hectares. These locations may have sustained the most damage from a tsunami catastrophe due to their proximity to the sea, low terrain and slope, and dense population. In consideration of the tsunami disasters in Aceh, we anticipate that tsunami risk maps will support

in the initiation of humanitarian and development activities in North Maluku Province.

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